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DIRECTORATE OF
INTELLIGENCE

Intelligence Report

Soviet Scientific and Engineering Manpower and Employment in R & D

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ER IR 72-11
September 1972

Copy No 7

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CENTRAL INTELLIGENCE AGENCY

Directorate of Intelligence

September 1972

INTELLIGENCE REPORT

SOVIET SCIENTIFIC AND ENGINEERING MANPOWER AND EMPLOYMENT IN R&D

SUMMARY

1. Stimulated by competition with the United States in the military field and in technology generally, the USSR has increased its stock of technically trained manpower enormously since 1950. In 1970 the number of natural scientists was four times the 1950 level and the number of engineers six times. At the same time, employment in research and development grew almost fivefold. Two-thirds of the natural scientists and about one-fourth of the engineers are employed in research and development (R&D)[1] together with a much larger contingent of supporting personnel. By 1970 the employment in R&D in the USSR was more than 2½ times that in the United States (see Figure 1).

2. During the last two decades the United States matched the Soviet rate of increase in the number of natural scientists and, in 1970, had a two-for-one edge over the USSR in the stock of natural scientists. In contrast, the number of engineers in the USSR grew much faster than the number of engineers in the United States. Although there are difficulties in determining the number of engineering graduates actively working as engineers, the USSR clearly has a wide lead in this regard (see Table 1).

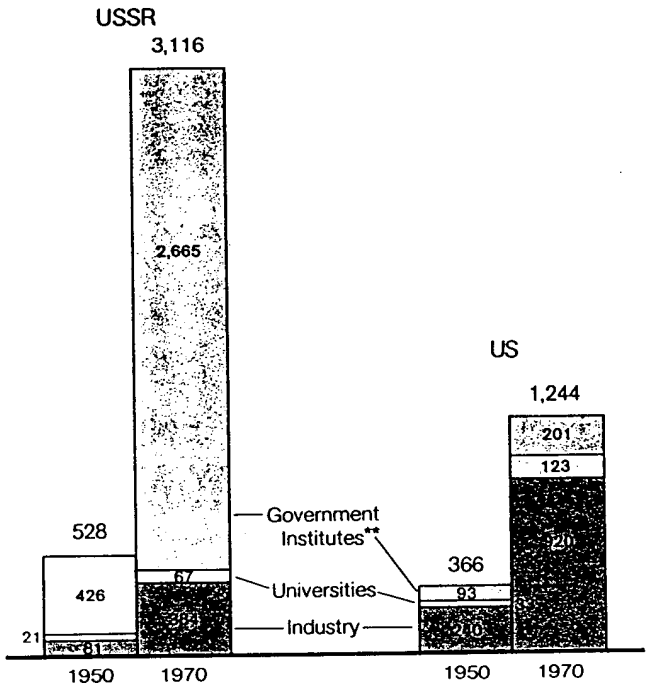
[1] As a working definition for this report, *research and development* is taken to include basic and applied research in science and engineering and the design and development of prototypes and processes. (*Basic research* is original investigation for the advancement of scientific knowledge; *applied research* is directed toward discovery of new scientific knowledge with specific product objectives; *development* is actively concerned with problems encountered in translating research findings or other general scientific knowledge into specific products.) The concept of R&D as used in this report also includes testing and evaluation, and thus is equivalent to the US concept of research, development, testing, and evaluation (RDT&E).

NOTE: This report was prepared by the Office of Economic Research and coordinated within CIA.

Figure 1

United States and USSR: Employment in R & D, by Type of Organization*

Thousand Persons



*See tables 12 and 13, in appendix A.

**In the United States, government institutes include federal government and other nonprofit institutions. The latter group employed 6,500 people in 1950 and 40,500 in 1970.

Table 1

United States and the USSR: Average Annual Rates of Growth of Science and Engineering Manpower

Percent

	Natural Scientists		Engineers	
	United States	USSR	United States	USSR
1951-55	7.3	5.7	8.1	8.4
1956-63	6.9	8.9	5.5	11.4
1964-70	8.0	6.3	2.6	8.3
1969-70	*NA*	5.3	*NA*	7.1
1951-70	7.4	7.2	5.1	9.6

3. Employment in the R&D sector in the USSR rose from 528,000 in 1950 to 3.1 million in 1970. During the 20 years 1950-70, the average annual growth was 9.3%, compared with a growth of 6.3% per year in employment in R&D in the United States. Growth was particularly rapid in 1956-62 when Soviet missile and space programs were going into high gear. Since 1962 the rate of annual additions to R&D manpower has been less than half the rate achieved earlier.

4. Compared with other estimates of employment in Soviet R&D, the estimates prepared for this report show a substantially higher rate of increase. For example, this report estimates that, during 1958-66, employment in R&D increased almost 12% per year. The USSR reported an increase of 9½% per year in employment in "science and scientific services"; an OECD report estimated the rate of increase to be nearly 10% per year in the same period; and an alternative estimate holds that R&D employment grew by 6½% per year.

5. Although Soviet R&D employment is more than 2½ times as large as in the United States, a number of problems of comparability prevent a direct comparison. For example, the number of scientists and engineers conducting or managing R&D in the USSR is estimated at 494,000 in 1970, compared with 545,000 in the United States.[2] Another significant difference in R&D employment in the two countries involves the support personnel in R&D. In the USSR there are approximately 5⅓ support workers per scientist and engineer conducting or managing R&D, compared with a ratio of about 1⅓ to 1 in the United States. Finally, three-fourths of the people employed in R&D in the United States are in private industry (see Figure 1). R&D employment in government and other nonprofit institutions in the United States amounts to only 16% of the total, in sharp contrast with the Soviet arrangements.

6. In the USSR, R&D is carried on primarily in institutes and facilities subordinate to government ministries. About 50% of the R&D establishments and 88% of the R&D employment are in this category, and most of them are tied to industrial ministries. Most of the remaining establishments and employees are in the Academies of Sciences, which employ 85,000 scientists and carry out much of the basic research performed in the USSR. The bulk of the developmental work is carried out in institutes attached to ministries. Research departments attached to enterprises play a relatively minor role, and university research is not nearly as important as it is in the United States.

7. As the scale of Soviet R&D increased, so did dissatisfaction with its performance. To some extent, manpower policies have been at fault. The proportion of the research talent allocated to universities and to Academies of Science is too large, and too little is allocated to the ministerial research institutes, which do the bulk of the applied research. Fundamentally, however, the fragmented organization and misdirected incentives of Soviet R&D have been at fault. The supply of trained manpower in general has been adequate.

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[2] This is an estimate of the number of scientists and engineers employed in R&D in a capacity that requires use of their technical education, including scientists and engineers who manage research and development programs.

INTRODUCTION

8. Western attempts to quantify the inputs of men, money, and materials channeled into Soviet R&D have been frustrated by the paucity of data. In particular, the number of workers engaged in either civilian or military R&D is not reported. The USSR, however, does publish information that bears indirectly on the R&D effort, such as the number of workers with engineering degrees and the number of persons classified as "scientific workers." Some Westerners have accepted these data at face value as a measure of Soviet technical manpower and have used them to make US-Soviet comparisons. As a result, Soviet achievements and capabilities vis-a-vis the United States have been overstated.

9. Soviet statistics carefully used, however, do provide a basis for making estimates of the level and rate of growth of engineering and scientific manpower in R&D. Other Soviet data can be used to estimate total R&D employment (scientists, engineers, and support personnel) and, to some extent, the occupational structure of the R&D labor force. These estimates are perhaps the best available representation of trends in Soviet R&D, and they permit guarded comparisons of Soviet and US employment in R&D.

10. This report presents estimates of the size and trends of total Soviet engineering and scientific manpower and the share employed in R&D activities. In addition, US-Soviet comparisons in these areas of activity are presented. Finally, the qualitative and organizational aspects of Soviet R&D manpower are examined.

DISCUSSION

THE STOCK OF SCIENTIFIC AND ENGINEERING MANPOWER

11. Soviet leaders have long realized that natural scientists and engineers were critically important to the primary Soviet military and economic goals. High wages, preferential housing and other special privileges, and compulsory job assignments have been used to direct the best talent toward employment in R&D. Ensuring an adequate supply of this talent has been a basic goal of the regimes' educational policy. Students receive early and comprehensive training in science and mathematics, and universities concentrate on turning out scientists and engineers.

12. The supply of scientific and engineering manpower has grown enormously since 1950. At the same time, substantial changes have occurred in the occupational composition of this technical elite, reflecting shifts in demand since the mid-1950s, most notably for skills associated with R&D in the weapons and space sector. Although the forced pace of development of a technical elite has involved some diminution in training standards, the quality of Soviet training and the caliber of leading scientists in many fields is as good as in the West.

Natural Scientists

13. Since R&D draws overwhelmingly from the natural sciences and from engineering fields, only these categories have been included in the discussion below. The Soviet Union does not publish data on the number of scientists as generally defined in the United States. The Soviet term "scientific workers" (*nauchnyye rabotniki*) is considerably broader in concept than the corresponding term used in the United States. Under the Soviet rubric, all employees with advanced degrees from universities, wherever employed, and all persons conducting research, regardless of educational background, are counted as scientific workers. More rigorously defined, scientific workers include:

> (a) academicians who are full or corresponding members of an Academy of Science;
>
> (b) all persons who have an academic degree of doctor or candidate of science, or an academic title of professor, docent, research associate, or assistant regardless of the place or character of work; and
>
> (c) other persons conducting research work in scientific institutions, industrial enterprises, and design organizations (moreover, the Soviet definition of "scientific workers" includes fields such as law and art which are not classified as "science" in the United States).[3]

14. Between 1950 and 1970, while the total civilian labor force was expanding by only 31%, the number of natural scientists increased 3 times (see Table 2), reflecting the relatively high priority given to scientific manpower. The rate of growth in the number of natural scientists rose markedly during the late 1950s and early 1960s, followed by a decline by about two-fifths at the end of the decade (see Table 1). Within the natural sciences, the number of persons in the fields of physics and mathematics—essential in military/space

[3] For a complete list of occupations classified under science in the USSR, see Appendix B.

Table 2

USSR: Distribution of Natural Scientists,[a] by Field [b]

Thousand Persons

Year	Total Natural Scientists	Physicists and Mathematicians [c]	Chemists	Biological Scientists	Geologists and Mineralogists	Agricultural Scientists	Medical Scientists
1950	70.9	10.2	12.9	8.6	3.6	14.1	21.5
1955	93.5	20.1	16.2	11.0	5.7	15.2	25.3
1958	112.5	22.6	20.2	13.2	8.2	18.6	29.7
1959	121.3	24.8	22.7	13.6	9.0	20.2	31.0
1960	134.4	29.0	26.2	15.1	10.7	21.2	32.2
1961	153.6	35.1	32.3	16.2	12.0	23.8	34.2
1962	167.7	48.3	25.4	21.6	13.4	25.5	33.5
1963	185.3	54.9	28.8	23.9	15.1	28.0	34.6
1964	195.1	58.2	31.6	25.7	15.4	29.1	35.1
1965	208.2	63.9	33.5	27.1	16.4	30.6	36.7
1966	225.8	70.8	36.7	29.8	17.5	31.7	39.3
1967	239.7	77.1	39.0	31.8	18.4	31.9	41.5
1968	256.0	83.0	41.7	34.1	19.3	33.3	44.6
1969	271.5	89.0	44.0	36.4	19.6	34.8	47.7
1970	284.1	95.3	45.8	37.3	20.3	35.4	50.0

[a] Enumerated under "Scientific workers."

[b] Same sources as for line 5 of Table 12, in Appendix A.

[c] Including geophysicists.

research—has grown by more than 8 times since 1950. In contrast, the number of agricultural scientists has increased 1½ times during this period. As a consequence, physicists, mathematicians, and chemists as a share of all natural scientists rose from one-third in 1950 to one-half in 1970.

Engineers

15. Soviet data on engineers (see Table 3) must be used cautiously, particularly when making comparisons with the United States. Soviet figures report the employment of persons with engineering degrees but overstate substantially the number of persons actually working as engineers. First, according to the 1959 census, about half of the employed persons with engineering degrees actually worked in managerial, administrative, or other non-engineering occupations.[4] For example, Leonid Brezhnev holds a degree in metallurgical engineering and therefore is counted as an engineer in government and administrative institutions. Second, 10%-15% of the engineering categories in the USSR are not counted as such in the United States. Geodesy and cartography, for example, are considered engineering occupations in the USSR but not in the United States. Third, since the late 1950s the Soviet Union has greatly expanded part-time education. Perhaps one-third of all engineering graduates since 1960 have received abbreviated, below-standard instruction in this system. Such graduates would not be considered to be professionally trained engineers

[4] CIA RR ER 63-12, *A Comparison of US and Soviet Professional Manpower*, May 1963, p. 17, UNCLASSIFIED.

Table 3

USSR: Distribution of Engineers, by Place of Employment [a]

Thousand Persons

Year	Total	Industry and Construction	Science and Science Service	Other [b]
1950	400.2	212.5	58.5	129.2
1955	597.8	319.8	89.4	188.6
1957	832.2	427.4	174.4	230.4
1960	1,135.0	600.1	264.4	270.5
1961	1,236.0	653.3	292.6	290.1
1962	1,325.1	687.2	324.3	313.6
1963	1,420.5	727.7	360.2	332.6
1964	1,497.5	753.1	391.2	352.9
1965	1,630.8	824.5	419.7	386.6
1966	1,789.0	897.4	469.2	422.4
1967	1,960.0	NA	NA	NA
1968	2,168.0	NA	NA	NA
1969	2,400.0	NA	NA	NA
1970	2,486.5	1,282.9	617.8	585.8

[a] Sources

1950-66—*Trud v SSSR*, Moscow, 1968, p. 268-269.

1967—*Narodnoye khozyaystvo SSSR v 1968 godu*, Moscow, 1969, p. 175 (hereafter referred to as *N. kh.*).

1968-69—*N. kh. 1969*, p. 134.

1970—*Narodnoye obrazovaniye, nauka i kul'tura v SSSR*, Moscow, 1971, p. 238.

[b] Including agriculture, transportation, communication, education, and government administration.

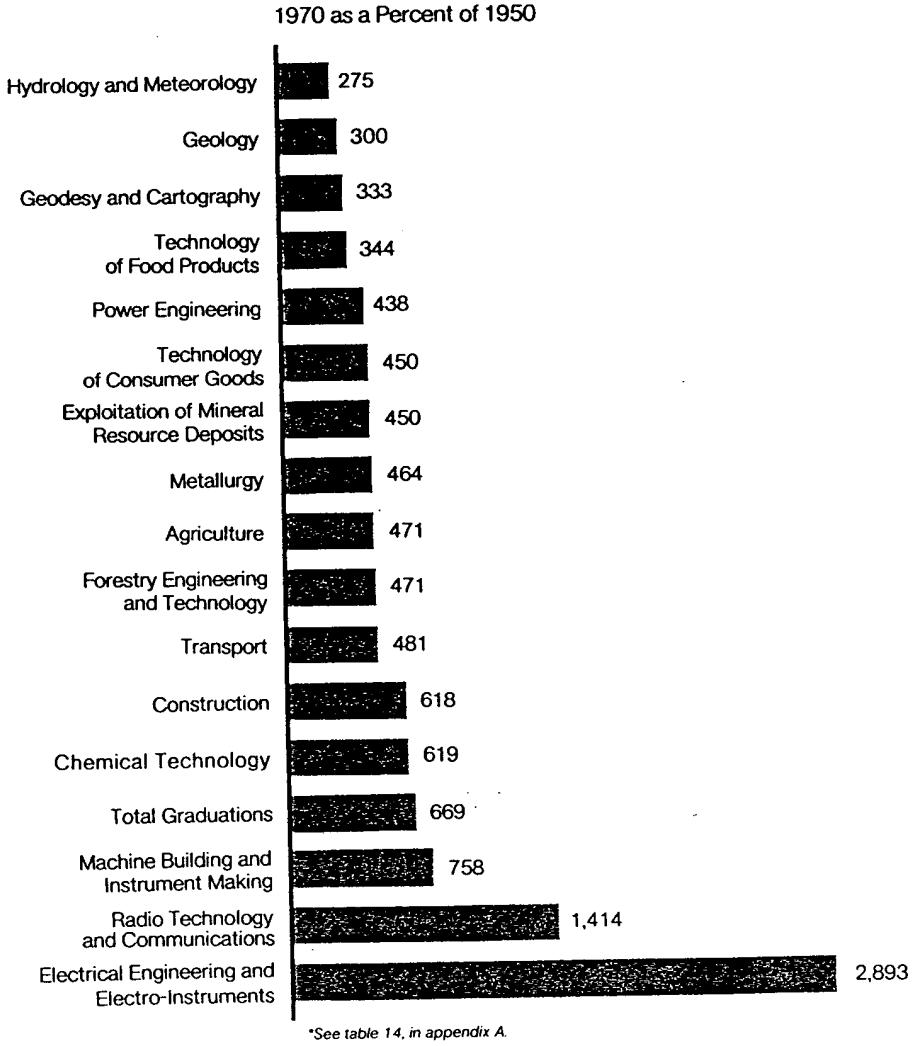
in the United States. Nevertheless, despite the incomparabilities, Soviet data are believed to show reasonably well the trends and areas of emphasis in allocating engineering manpower.

16. The pattern of growth of engineers resembles the growth of natural scientists: rapid growth since 1950 with the greatest increase in the 1955-63 period, followed by a marked slowdown in the late 1960s (see Table 1). Between 1955 and 1970 the number of employed persons with engineering degrees quadrupled. Although the number of engineers increased greatly in all sectors of the economy except agriculture, science and scientific service organizations were particularly favored. During 1956-70 the number of engineers employed in science and scientific services increased by 6 times. Between 1955 and 1970 the proportion of engineers found in scientific institutions rose from about 15% to 25% of all engineers.

17. The relative priorities attached to the various engineering specialties can be inferred from the data on the annual graduations shown in Figure 2. Primarily because of defense requirements, growth of engineering employment was most rapid in the fields of machine building and instrument making, electrical and electronic equipment, and radio technology, areas of specialization which are engaged heavily in the support of military and space programs. In 1970, graduations in these fields were 5 to 28 times greater than in 1950. At the other end of the scale, graduations in the fields of geology and survey of mineral resources, hydrology and meteorology, geodesy and cartography, and food technology were only 2 times greater.

Figure 2

USSR: Annual Graduations of Engineers, by Field *



*See table 14, in appendix A.

US-USSR Comparisons

18. Conceptual differences in statistical reporting hinder meaningful, direct comparisons of natural scientists in the United States and USSR and prevent altogether comparisons of engineering employment. Because the definition of scientist and engineer is narrower in the United States than it is in the USSR, Soviet engineering and scientific manpower is overstated relative to that in the United States.[5] Bearing in mind the limitations imposed by the data, comparisons

[5] In the United States, engineers represent all persons actually engaged in chemical, civil, electrical, mechanical, metallurgical, and all other types of engineering work at a level which requires knowledge of engineering, physical, life, or mathematical sciences equivalent at least to that acquired through completion of a four-year college course with a major in one of these fields. (An engineer need not hold a college degree in the field.)

Functionally, persons with the above qualifications are included if they are in research-development, production, management, technical service and sales, and other positions which require them to use the indicated level of knowledge in their work. Excluded are persons trained in engineering but currently employed in positions not requiring the use of such training.

of scientific and engineering manpower in the two countries nevertheless provide some insight as to Soviet strengths and relative priorities.[6] The following points stand out when such comparisons are made:

(a) Between 1950 and 1970 the rate of growth in the number of natural scientists in the two countries was about the same.

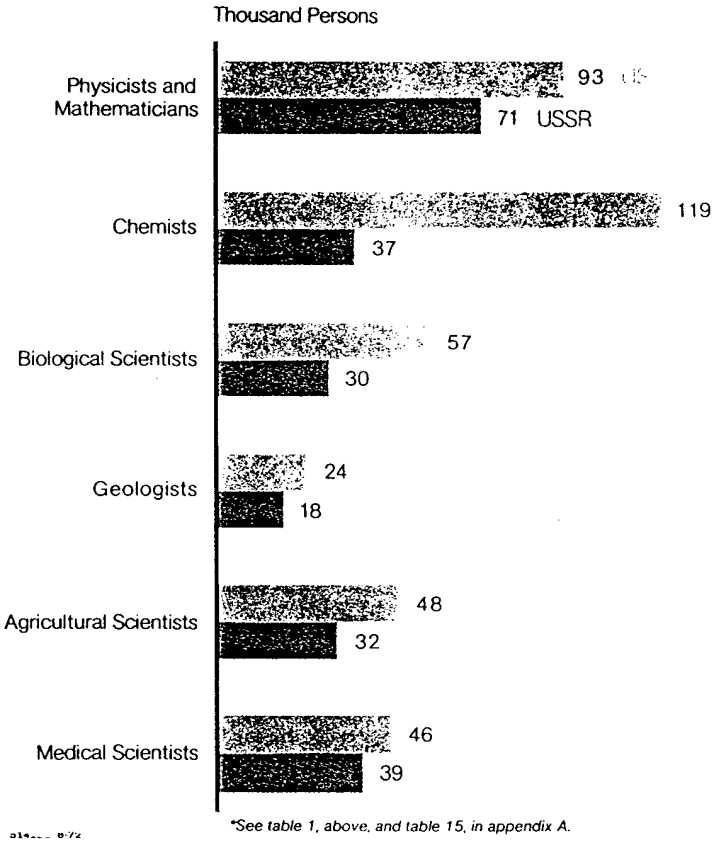
(b) In 1966 the difference in the number of natural scientists in the two countries was most pronounced in chemistry and least in geology (see Figure 3).

(c) Fluctuations in the rate of increase of scientists and engineers have been less pronounced in the United States than in the USSR, and the missile-space buildup in the late 1950s and early 1960s is not nearly as apparent in the United States as in the USSR. Since the 1950s the United States has witnessed a decline in the rate of growth of engineering manpower (see Table 1).

(d) Unlike the situation in the USSR, the rate of growth of natural scientists in the United States has exceeded the rate of growth of engineers.

Figure 3

United States and USSR: Comparison of Natural Scientists, 1966*



*See table 1, above, and table 15, in appendix A.

[6] The number of persons in the United States employed in science and engineering positions is shown in Table 15, in Appendix A.

(e) In 1950 there were more than twice as many natural scientists in the United States as in the USSR and by 1970 the gap between the two countries still had not narrowed appreciably. Nevertheless, the United States, which had about 3½ times as many physicists, mathematicians, and chemists as the Soviet Union in 1950, had only twice as many by 1966 (the last date for which US data are available), as shown in Table 2, above, and Table 15, in Appendix A.

(f) The rate of growth in the number of engineers in the United States between 1950 and 1970 has been only about one-half that recorded for the USSR during the same period.

THE ALLOCATION OF SCIENTIFIC AND ENGINEERING MANPOWER TO THE R&D EFFORT

The Soviet Official Series

19. Although the Soviet Union regularly reports the employment of persons with science or engineering degrees, some detective work is needed to determine how many of them are working in research and development.

20. Two published series on employment—"science and science services" and "scientific workers"—together include most persons engaged in R&D, but they also contain many people not involved in R&D. The coverage of these two series is depicted in Figure 4. In terms of organizations included, the definition of "scientific workers" is broader because it counts the administrative and professional staffs employed in all of the institutions conducting R&D—scientific research organizations that are subordinate to ministries or the Academies of Sciences,[7] enterprises performing their own research, and universities. The series "science and science services," on the other hand, covers only persons employed in scientific research organizations but includes all of the people employed in these organizations—administrative staffs, researchers, and lesser-skilled support workers. Thus the two series overlap in that both include the administrative and professional staffs at scientific research organizations, and each fails to cover completely all persons actually engaged in R&D.[8]

21. Incomplete coverage, however, is not the whole problem. Both series also report many persons who are not involved in R&D as it is usually defined. The "science and science services" category includes, for example, meteorologists

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[7] Including employment in the following main categories of organizations: (a) scientific research establishments (specifically, academies, institutes, observatories, archives, botanical gardens, museums, and libraries engaged in scientific work and, in addition, all computer centers); (b) surveying and geological exploration; (c) independent design organizations and selected experimental stations; (d) "establishments of the hydrometeorological service"; and (e) auxiliary establishments serving scientific organizations such as machine-testing stations (N. K. Sazanovich (ed), *Metodicheskiye ukazaniya k sostavleniyu gosudarstvennogo plana razvitiya narodnogo khozyaystva SSSR*, Moscow, 1969, p. 757-759).

[8] Professional staff is defined to include researchers and technicians performing jobs requiring the equivalent of a college education; the nonprofessional staff includes clerical and other service workers performing tasks not requiring a college education.

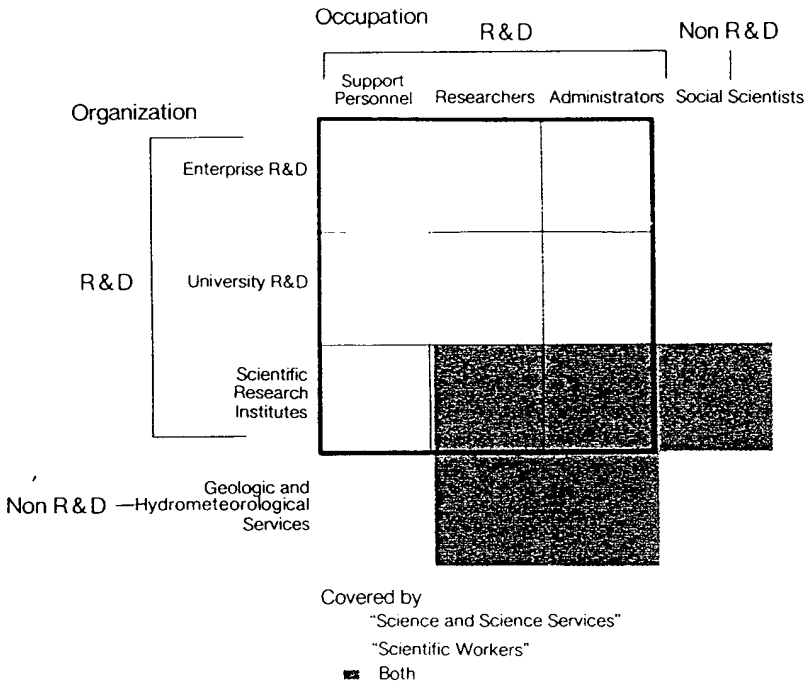
assigned to weather forecasting, and holders of advanced degrees are counted as "scientific workers" whether they work in R&D or work full time in administration or university teaching.

22. Despite these limitations, the published employment series can be refined to provide reasonably accurate estimates of employment in Soviet R&D. These estimates describe a development of the Soviet R&D effort that is different from either of the official series and from other independent estimates.

23. The estimates of Soviet R&D manpower used here were derived through adjustments to the two published manpower series on science workers (as suggested in Figure 4) and by making estimates for those R&D workers not covered by either series. Briefly, R&D manpower was estimated as follows. First, persons who are included in the two series but who are not engaged in R&D were eliminated, workers in the geologic and hydrometeorological services were deleted from the "science and science services" series, and social scientists were deleted from the "scientific worker" series. Second, estimates were made of R&D support personnel not included in either series. Summing the results of these procedures—avoiding double counting where it occurs—yields estimates of total R&D employment in the USSR.[9]

Figure 4

Coverage of the Two Published Soviet Series on Science Employment



[b] For details of methodology and for sources, see Table 12, in Appendix A.

Trends in Employment in R&D in the USSR

24. During the past two decades, total employment in R&D in the USSR grew from an estimated 528,000 in 1950 to over 3.1 million in 1970 (see Table 4). This fivefold increase includes the employment of all those associated with R&D—researchers, administrators, laboratory technicians, clerical staff, char force, and others. As a share of the country's total labor force, R&D employment rose from 0.5% to 2.5% between 1950 and 1970.

25. The rate of growth in R&D manpower has fluctuated sharply since 1950 (see Table 5). The tremendous rate of growth in total R&D manpower between 1955 and 1962 supported the burgeoning aircraft, missile, and space programs. Since 1963 the rate of increase has returned to roughly the pre-1955 level. The more highly educated component of the R&D labor force did not grow at the same pace as all R&D manpower or even that part of it possessing the equivalent of a college education. Holders of advanced degrees increased very rapidy in 1951-55. Then in 1956-62, the graduate schools could not keep up with the general expansion in R&D employment. As the graduate school enrollments climbed, however, the rate of increase of advanced degree holders employed in R&D made a marked recovery in 1963-70. Thus, considering quality, the rate of expansion of R&D manpower was somewhat slower before 1963 than indicated by total employment and faster after 1963.

26. The end result of these fall-behind and catchup phases of graduate education was probably some decline in the share of physicists, mathematicians, geologists, and biologists and an increase in the proportion of medical scientists having advanced degrees in R&D employment. At least this was true of the entire stock of natural scientists (see Table 6).

Table 4

USSR: Employment in R&D

Thousand Persons

1950	1955	1960	1965	1970
528	704	1,458	2,317	3,116

Average Annual Percentage Rate of Growth

1951–70	1951–55	1956–60	1961–65	1966–70
9.3	5.9	15.7	9.7	6.1

Table 5

USSR: Average Annual Rates of Growth of R&D Manpower

Percent

Period	Total	Non-Professional Staff	Scientific Workers	
			Total	With Advanced Degrees
1951-55	5.9	6.0	5.5	10.4
1956-62	15.4	15.8	13.8	7.3
1963-70	6.2	5.9	7.5	9.6
1951-70	9.3	9.3	9.1	9.0

Table 6

USSR: Advanced Degree Holders
as a Share of Natural Scientists, by Field

Percent

	1955	1962	1970	Net Change 1955–70
Physicists and mathematicians	30.8	20.7	26.3	−4.5
Chemists	32.0	32.2	31.9	−0.1
Biological scientists	59.0	46.3	52.8	−6.2
Geologists and mineralogists	48.5	35.8	43.4	−5.1
Agricultural scientists	44.6	34.2	44.9	0.3
Medical scientists	60.1	55.4	67.0	6.9

27. Data from the "scientific workers" series indicate that, in 1950-60, about four-fifths of the college graduates associated with state "scientific research institutes" were actually conducting or managing research and development (see Table 7). Projecting this relationship forward and adding the scientific workers

Table 7

USSR: Jobs Performed by "Scientific Workers" in "Scientific Research Institutes" [a]

Thousand Persons

	1950		1955		1960	
	Total	With Advanced Degrees	Total	With Advanced Degrees	Total	With Advanced Degrees
All jobs [b]	79.5	20.8	96.7	31.1	200.1	44.8
Administrators	20.2	8.9	22.1	10.8	40.9	16.7
Researchers	37.1	11.3	53.4	19.2	104.0	27.1
Other [c]	13.2	0.6	21.0	1.1	55.2	1.0

[a] *Vysshoye obrazovaniye v SSSR*, Moscow, 1961, p. 208–209. Data are from the "scientific workers" series.

[b] "Scientific research institutes" employ approximately one-half of all college graduates associated with R&D. College graduates are also employed in R&D activities at higher education institutions and at industrial enterprises.

[c] Including technicians and laboratory assistants.

performing R&D at universities and industrial enterprises indicates that, in 1970, approximately 494,000 of the 622,000 scientific workers employed in R&D were either performing research and development or managing R&D programs.[10]

Military Scientists

28. Of the scientists associated with R&D, military scientists deserve special mention. This group (classified as "other" scientists in Soviet statistics) includes scientists from various fields whose specialty is the application of their training

[10] In 1970, there were 128,000 scientific workers performing or managing R&D projects in industrial enterprises and 57,000 in universities. In addition, 10,000 graduate students performed R&D. It is estimated that 30% of the 427,000 scientific workers in "scientific research organizations" worked as technicians and laboratory assistants, leaving 299,000 scientific workers conducting or managing R&D projects.

to military requirements.[11] In 1950, about 98% of this group of 3,600 were teaching in military academies. In a real sense, these academies are not only military establishments but also institutions for training the professionals in the armed forces who conduct military R&D and direct and supervise the design, development, and procurement of weapons and military equipment.[12] By 1962 the number of military scientists had doubled from the 1950 level, reaching 7,176.[13] In 1963 the number of military scientists was given as twice the 1962 level, without explanation [14]; the category apparently was redefined that year to include military scientists heretofore not counted. Most likely, the additions included military scientists working in military research laboratories. Since 1963 the number of military scientists has grown at an average annual rate of 10.3%, compared with an average rate of 6.2% per year for all R&D employment.

Trends in the Allocation of R&D Manpower

29. Although bafflingly complex and shrouded in secrecy, Soviet R&D is carried on in roughly three areas: (a) specialized R&D institutes, design organizations, and experimental testing facilities (these are subordinate either to the Academies of Sciences or to government ministries), (b) higher education institutions, and (c) industrial enterprises.

30. The institutes and facilities subordinate to government ministries are the bedrock of the Soviet R&D effort, accounting for about 50% of the nearly 5,000 science establishments in 1970,[15] and 86% of all R&D employment. In 1950 this sector of R&D accounted for one-third of the science establishments and 81% of R&D employment. The remaining R&D employment was found at enterprises and universities. R&D conducted by ministries is heavily weighted toward industry: About 40 of the nearly 60 Soviet ministries are industrial ministries which employed over 1.1 million R&D workers in 1968, or about one of every three persons engaged in R&D (see Table 8). If the R&D work force in industrial enterprises is lumped with the R&D employment in institutes subordinate to industrial ministries, total R&D employment associated with industry rises to about one-half of all R&D employment.

31. Between 1961 and 1968, R&D employment in industrial ministries rose at an average annual rate of 5.9%. Unlike other areas of R&D, the growth of employment in industrial R&D performed by institutes subordinate to ministries was particularly rapid in the late 1960s, rising at an average rate of more than 10% from 1965 to 1968. At these institutes, approximately one-half of the R&D personnel were engaged in testing and evaluation work, 30% were in research, and the remaining 20% were in development.

32. Few data are available on employment in R&D, by branch of industry. More specifically, no data are available on the magnitude of employment in defense-related R&D in industry. One Soviet source reveals that, in 1968, in-

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[11] *Byulleten', ministerstva vysshego i srednegospetsial'nogo obrazovaniya* SSSR, no. 9, 1963, p. 8.

[12] Nicholas DeWitt, *Education and Professional Employment in the USSR*, Washington, 1961, p. 221.

[13] *N. kh. 1962*, p. 583.

[14] *N. kh. 1963*, p. 590.

[15] *Narodnoye obrazovaniye, nauka i kul'tura v SSSR*, Moscow, 1971, p. 243.

Table 8

USSR: R&D Performed by Industrial Ministries

	Number of R&D Units			Employment (Thousand Persons)		
	1961	1965	1968	1961	1965	1968
Laboratories (research)	23,644	25,788	33,000	236.4 [a]	257.9 [a]	330.0 [a]
Design organizations (development)	11,227	13,378	15,000	120.2 [b]	148.5	223.0
Testing-experimental organizations (testing and evaluation)	NA	NA	NA	397.4 [b]	434.0	573.1
Total industrial R&D (narrowly defined) [c]	NA	NA	NA	754.0	840.4	1,126.1
Total industrial R&D (including enterprise R&D) [d]	NA	NA	NA	883.0	996.4	1,372.1

[a] Estimate based on the number of employees and number of laboratories in several republics for several years.

[b] Data for 1960. B.F. Zaytsev and B.A. Lapin, *Organizatsiya planirovaniya nauchno-tekhnicheskogo progressa*, Moscow, 1970, p. 15.

[c] Excluding employment of persons in R&D activity if carried on in industrial enterprises on their own account.

[d] Including enterprise R&D from line 17 of Table 12, in Appendix A.

dustry employed nearly 426,000 "scientific workers" [16]—the highly trained segment of the R&D work force (see Table 9). Of this total, three out of four

Table 9

USSR: "Scientific Workers" in Industry [a]

Persons

	1965	1968
Total scientific workers in industry [b]	356,810	425,992
Of which:		
Machine building and metalworking	247,625	302,170
General machinery, instrument making, electrical-technical, and radio-electronics	73,293	NA
Chemicals	50,791	62,096

[a] Based on N.B. Vornin (ed), *Ekonomicheskiye problemy effektivnosti nauki*, Moscow, 1971, p. 77, 79.

[b] Employed in the various categories of industrial R&D shown in Table 8.

were employed in the machine building and metalworking branch (MBMW). Since MBMW employs one-third of the total industrial labor force and is responsible for about 30% of industrial production, its share of the R&D effort is disproportionately high. Moreover, military hardware constituted a substantial share of total MBMW output in the 1960s; therefore, much of the R&D labor force in this branch was undoubtedly working on military R&D. Ministries not related to industry—such as the Ministries of Agriculture, Construction, Health, Education, Communications, Defense, and the like—also employ upwards of one-third of the total R&D work force in their research facilities.

[16] These workers are scattered among the various categories of industrial R&D employment shown in Table 8.

33. Next in importance is employment of over 85,000 scientists in 20 academies of science, the most prestigious science institutions in the country.[17] These academies, the oldest of which was established in 1725, are engaged primarily in basic research and have no counterpart in the United States. In the USSR Academy of Sciences, in 1965, there were 4,978 scientists in the physical-technical and mathematical sciences departments supported by 12,560 auxiliary workers. In the chemical and biological sciences departments there were 5,132 scientists and 11,361 auxiliary workers.[18] The academies of science restrict their activities largely to basic research, leaving the development phase to institutes of the ministries and to enterprises.

34. R&D performed at universities is not nearly as important in the USSR as it is in the United States. In 1970, Soviet universities accounted for only 2% of the total R&D work force, compared with about 10% in the United States. There are 51 research institutes located in Soviet universities, but these are either small scientific organizations or institutes operating on a volunteer basis.[19] University research has been characterized by one Soviet source as being "performed by the academic departments' instructors during the so-called 'second half of the working day.' Research departments and sectors play a purely administrative and managerial role. It is not surprising that many years of attempts to conduct integrated research using the forces of a group of departments have produced virtually nothing."[20]

Occupational Structure of R&D Employment

35. The Soviet policy of maintaining a high degree of central control is evident in the organizational structure of R&D, as the most important R&D is performed not at the production level (enterprises) but rather at the administrative level (ministries). The highly formal structure of R&D is carried down to the occupational level with duties and responsibilities carefully spelled out (see Appendix C).

36. Both Soviet and Western experts have stressed the importance of having a proper mixture of administrators, researchers, technicians, and auxiliary workers in achieving a productive research program. Data on the structure of employment in R&D in both the United States and USSR are sketchy. In 1970, there were approximately 494,000 scientists and engineers conducting or managing R&D programs in the Soviet Union, supported by about 2½ million other workers. In contrast, the United States had approximately 545,000 researchers (scientists and engineers) supported by about 700,000 other workers in 1970 (see Figure 5).

37. The abundance of support personnel, however, masks a severe shortage of professionally trained technicians. A series of surveys of research institutes subordinate to the Ministry of Instrument Making, while perhaps atypical, provides some insight into the structure of employment in R&D. Approximately

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[17] *Narodnoye obrazovaniye, nauka i kul'tura v SSSR*, Moscow, 1971, p. 245.

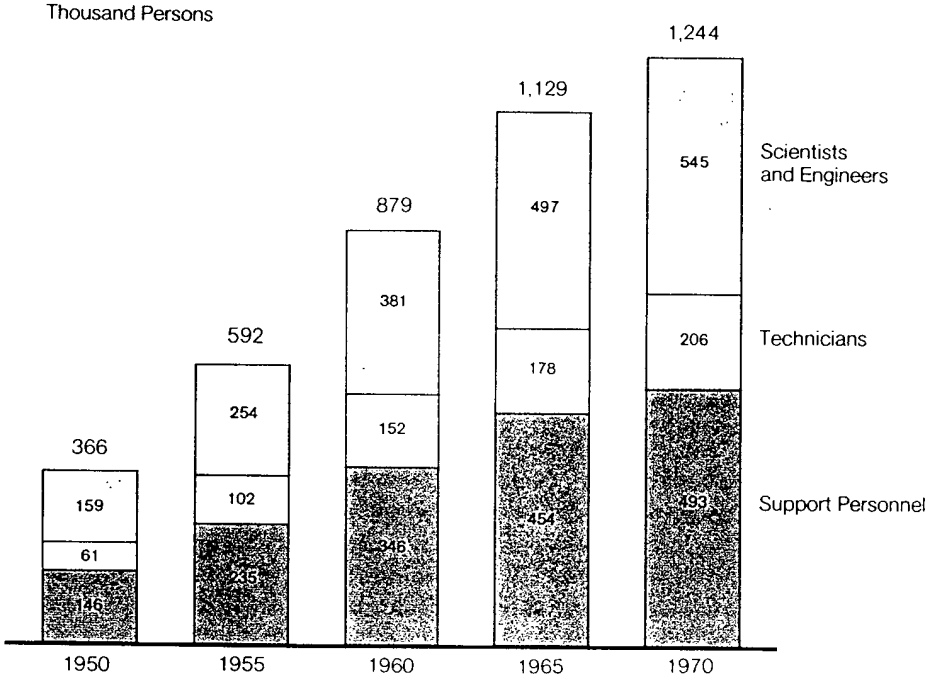
[18] D.I. Valenty and I.F. Sorokin (eds), *Naseleniye trudovyye resursy SSSR*, Moscow, 1971, p. 284.

[19] *Izvestiya*, 22 January 1972, p. 5.

[20] *Ibid.*

Figure 5

United States: R&D Employment, by Occupational Category*



*See table 13, in appendix A. Because of rounding, components may not add to the totals shown.

one-half of the staffs of the institutes was composed of workers classified as engineering-technical personnel and divided by occupation as follows [21]:

Occupation	Percent of Engineering-Technical Staff
Researcher	56.2
Designer	25.6
Technologist [a]	5.0
Supply and service personnel	13.2

[a] Technologists are responsible for translating blueprints and technical documents into production models.

Thus, in these institutes, the researchers constituted about one-fourth of the entire staff, and the ratio of researchers to support personnel was approximately 1 to 3.

38. Soviet experts argue that shortages of technicians, the skilled manpower which performs routine but technical jobs that otherwise must be done by researchers, foster inefficiencies in R&D. From scattered data, it appears that the ratio of researchers to technicians is not more than 1 to 0.3, compared with the ratio of 1 to 1.5 or 1 to 2 that is deemed optimal by a Soviet expert.[22] Moreover, one expert claims that the majority of Soviet research labs employ only one-fifth as many technicians as analogous labs in the United States, Switzerland, and West

[21] P.N. Zavlin, A.I. Shcherbakov, and M.A. Yudelevich, *Trud v sfere nauki*, Novosibirsk, 1971, p. 319.

[22] *Ibid.* p. 304.

Germany.[23] Workers in prototype construction are also fewer than desired and average less than one for every five researchers, compared with the goal of one per four to five researchers.

39. Surprisingly enough, the Soviets also assert that they are short of unskilled and semi-skilled workers in R&D. The results of a study of 66 laboratories in instrument making research institutes (see Table 10) indicated shortages of workers ranging from one-half to three-quarters of recommended levels.

Table 10

Actual and Recommended Staff Positions in Laboratories of the Research Institutes of the Soviet Ministry of Instrument Making [a]

Persons

Position	Actual	Recommended
Director of laboratory	1.0	1
Deputy director of laboratory	...	1
Head engineer	2.5	2–3
Senior engineer	4.5	4–5
Engineer	7.5	8–10
Technician	4.5	15–20
Auxiliary worker (lab assistants, secretaries, etc.)	0.2	2–3
Total	20.0	35–45

[a] *Ibid.*, p. 306.

40. Some design work is performed within research institutes. Five to six percent of the workers in the surveyed research institutes were designers.[24] The majority of design work, however, is carried out by separate design organizations which are responsible only for design and development work. Design bureaus account for approximately one-fifth of total R&D employment by industrial ministries (see Table 8). As in research labs, there are serious shortages of technicians in design bureaus, and the situation worsened during the early and mid-1960s (see Table 11). In 1966, there were 0.7 technicians per engineer in design organizations compared with a recommended ratio of 3.4 technicians per engineer.[25]

41. One-half of the R&D employment in industrial ministries is in testing-evaluation organizations (see Table 8). The responsibilities of these organizations and the composition of their staffs are not known.

42. Soviet progress in R&D has been retarded by numerous factors, including shortages of laboratories and equipment and enterprise managers who have tended to resist innovations because of the nature of the incentives set for them by the central authorities. Even if these faults were corrected, however, the organization and structure of Soviet R&D would remain a major defect. According to Soviet reports, the artificial organizational separation of establishments performing research, design, and testing, and particularly the limited amount of R&D performed by industrial enterprises, results in bottlenecks and failures of coordination.

[23] *Ibid.* p. 303-304.

[24] *Ibid.* p. 323.

[25] *Ibid.* p. 326.

Table 11

USSR: Staff Positions in Design Bureaus as a Share of Total Professional Employment [a]

Percent

Position	1963	1966
Administrator	1.3	1.9
Head designer	7.3	9.8
Senior engineer	12.9	18.8
Engineer	23.3	28.1
Senior technician	27.3	24.1
Technician	19.6	14.3
Draftsman	8.3	3.0
Total	**100.0**	**100.0**
Ratio of engineers to technicians	1:1.2	1:0.7

[a] *Ibid.*, p. 327.

43. One aspect of the organizational problem involves the misallocation of R&D manpower. Forty percent of all advanced degree holders are employed by universities, but they account for only 4% of science research.[26] In large part, R&D in Soviet universities is starved for equipment and materials. In 1965, expenditures per R&D worker in universities for these items was only one-fourth the amount spent in research institutes.[27] A 1966 decree ordered that the situation be corrected, but reportedly nothing yet has been accomplished.[28] Ministerial research institutes, on the other hand, have relatively large amounts of equipment and materials but are short of people with advanced degrees or even with a university education: in 1966 only 43% of their professionals (administrators and researchers) had a higher education.[29]

44. Although universities and ministerial research institutes have their problems, the enterprise research institute, which lacks both men and money, is in the worst shape of all Soviet R&D elements. Through at least the late 1950s and early 1960s, moreover, the situation at enterprise laboratories deteriorated as the higher paying scientific research institutes attracted qualified personnel employed in industry. (Between 1960 and 1966 the share of engineers with a higher education employed in industry laboratories declined from 15.8% to 14.6%.)[30] Between 1955 and 1966 the average number of people employed in the design and research labs at enterprises declined from 24 to 17 and the number of university trained engineers, from 10 to 6.[31]

US-USSR Comparisons

45. As long ago as 1950 the number of persons working in Soviet R&D was half again as large as the number working in R&D in the United States (see Figure 1). During 1951-70 the USSR enlarged its R&D labor force at

[26] *Izvestiya*, 22 January 1972, p. 5.

[27] Zavlin, Shcherbakov, and Yudelevich, *op. cit.* p. 58.

[28] *Ibid.*

[29] *Voprosy ekonomiki i planirovaniya nauchnykh issledovaniy*, Moscow, 1968, p. 69. (tr by Air, FTD)

[30] Zavlin, Shcherbakov, and Yudelevich, *op. cit.*, p. 59.

[31] *Ekonomika i organizatisya promyshlennogo proizvodstva*, no. 4, 1971.

a substantially greater rate than did the United States—9.3% per year compared with 6.3% per year. As a consequence, total R&D employment in the USSR grew to more than 2½ times the US level by 1970. The Soviet commitment to R&D can also be traced in the rising share of the labor force engaged in R&D, which increased from 0.6% in 1950 to 2.6% in 1970. In the United States, R&D employment accounted for 0.6% of the labor force in 1950 and 1.4% in 1970.

46. There is, however, no Soviet advantage in the number of scientists and engineers conducting or managing R&D projects. According to the estimates in paragraph 36, the USSR had 494,000 of these people in 1970 while the United States had 545,000.

47. In addition, the organization and structure of Soviet R&D prevents the USSR from making the most of its manpower. The lack of attention paid to enterprise research in the USSR has hindered technological development. Only 12% of R&D workers are employed in industrial enterprises, a situation very different from that in the United States[32] (see Figure 1). On the one hand, plants facing day-to-day problems with production are best able to see problems and opportunities. With little or no R&D capabilities, however, these plants must rely on outside help. On the other hand, research institutes, unfamiliar with the capabilities and problems of the plants they serve, tend to develop solutions that cannot be implemented. For example, "up to 40% of the plant designers are occupied in unproductive work in correcting projects developed by research institutes that do not meet the plant's production capabilities."[33] As a result, the average time from research to production in Soviet industry is five to ten years, whereas more than 90% of the research projects in US industry are completed in less than five years.[34]

48. Although the people concerned with Soviet R&D have long recognized the importance of beefing up enterprise R&D, not much has been done in this area. A comparison of the growth of employment in major organizational components of R&D shows a sharply contrasting development in the United States and the USSR. In the USSR, employment in government institutes ("scientific research institutes") grew much faster during 1951-70 than employment in R&D at enterprises (see Figure 1). In the United States, however, growth of R&D employment in government was only about two-fifths that in enterprises.

49. The USSR's R&D effort during the past two decades has resulted in technological progress matching the progress of the developed West in most areas. In making these gains, however, the USSR has had to employ substantially more R&D workers than the West. This relative inefficiency stems from the factors discussed above and other factors outside the sphere of R&D related to the organization and management of the economy.

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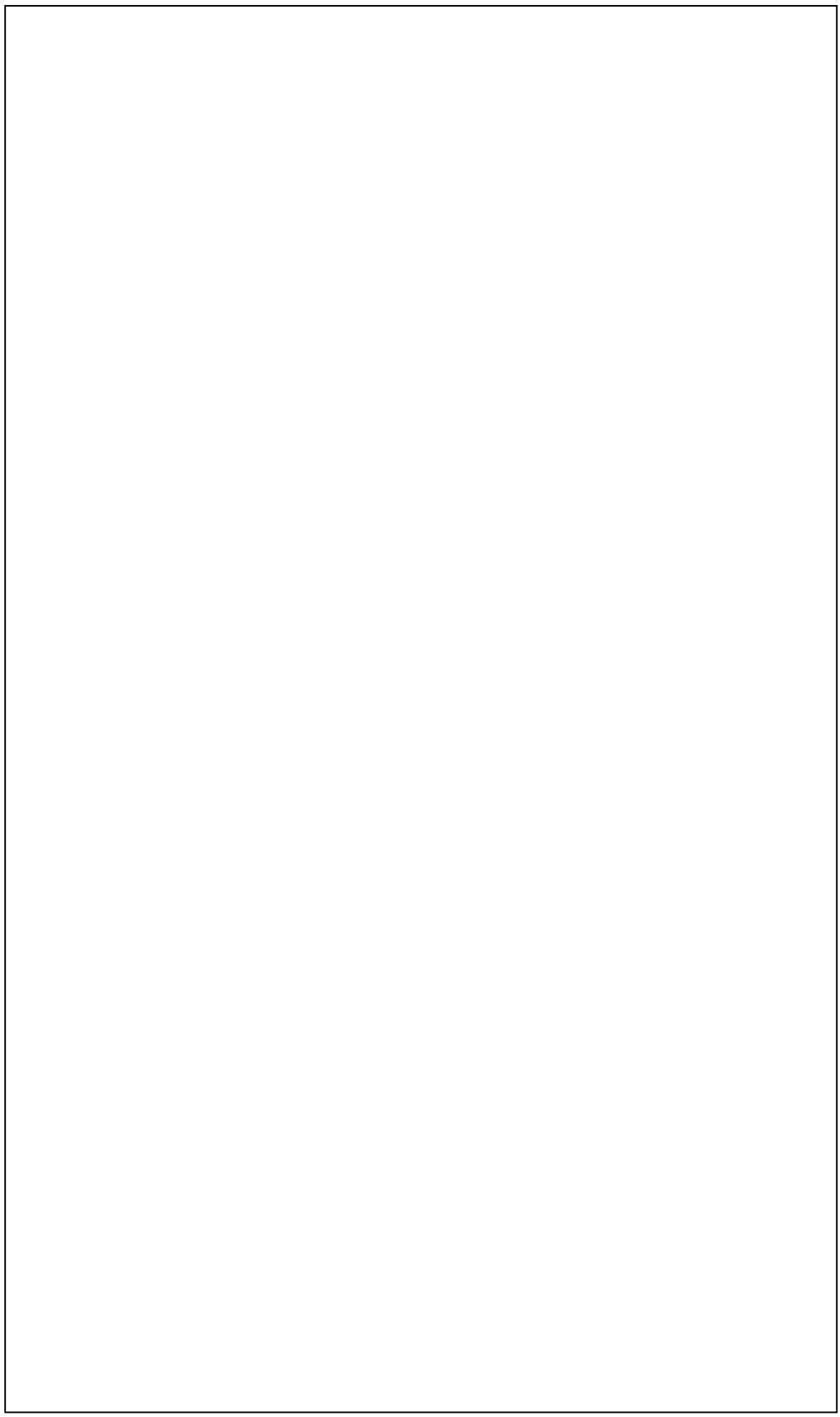
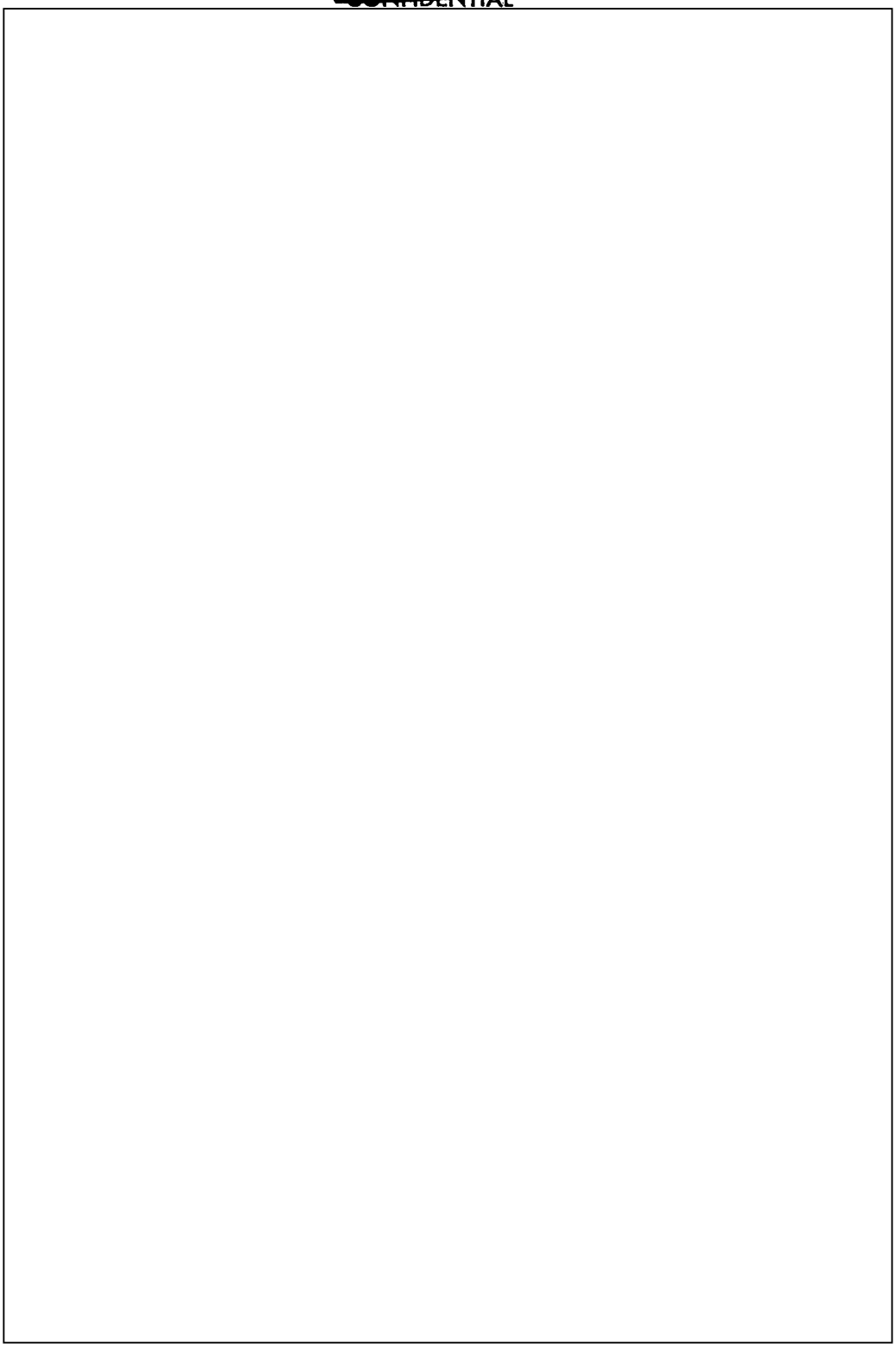
[32] In terms of quality, the share may be even smaller because a wage differential of 20%-40% draws the better researchers out of industry and into higher-paying institutes. (*Pravda*, 15 January 1972, p. 3.)

[33] *Voprosy ekonomiki i planirovaniya nauchnykh issledovaniy*, Moscow, 1968, p. 13. (tr by Air, FTD)

[34] Zavlin, Shcherbakov, and Yudelevich, *op. cit.* p. 133-134.





APPENDIX A

Estimates of Employment in US and Soviet R&D Activity, 1950-70

Neither the United States nor the USSR publish data on total employment in R&D activity. Other data, however, are published that allow the construction of such estimates. Although the series for the two countries were made as comparable as possible, the wide differences in reporting in the two countries and ambiguities in Soviet reporting require caution in making direct comparisons. In particular, a number of persons are included on Soviet R&D rolls who are not counted in the United States. It is suspected, therefore, that the estimate for total employment in Soviet R&D may be significantly inflated when compared with the estimate for the United States. On the other hand, it is believed that the two series do reflect with considerable accuracy the trends in R&D activity in the United States and USSR between 1950 and 1970.

The estimates of total Soviet R&D manpower shown in Table 12 were derived through adjustments to the two published manpower series on scientific workers (see Figure 4). Briefly, the estimates were derived as follows. First, employment in geologic-prospecting and hydrometeorological services was deducted from total "science and science services" employment. Second, social scientists were deducted from the "scientific worker" category. Third, the number of scientific workers at academic institutions is reported, but only part of their time is spent in R&D activity. Soviet sources indicate that all persons in research in higher education establishments should, for purposes of accounting, be counted as only one-third. This coefficient was used to derive the estimate for academic research. Finally, estimates were made for the number of persons engaged in R&D activities in industrial enterprises. In sum, the estimate includes (1) all persons employed at scientific research institutes (less geologic and hydrometeorological organizations and social scientists) and project and design organizations and (2) an estimate of full-time equivalent research being conducted at higher educational institutions and at enterprises.

Data on the number of scientists and engineers engaged in R&D activity in the United States, by sector, are published for selected years between 1950 and 1970 (see Table 13). Estimates were made of the number of technicians and other support personnel in order to make the US data comparable with Soviet data.

Tables 14 and 15 present detailed data that bear on the R&D effort in the two countries. All data in the two tables are from official government sources in the United States and USSR. As discussed in the text, differences in definitions and coverage make it impossible to compare data directly on engineers in the two countries.

Table 12

USSR: Employment in R&D [a]

Thousand Persons

	1950	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1. Total "science and science services" employment	714	992	1,094	1,208	1,326	1,462	1,763	2,011	2,213	2,370	2,497	2,625	2,741	2,850	2,990	3,128	3,238
2. Geologic and hydrometeorological services	277	398	421	427	445	440	436	427	434	453	465	465	467	470	475	479	484
3. Employment at scientific research institutes	437	594	673	781	881	1,022	1,327	1,584	1,779	1,917	2,032	2,160	2,274	2,380	2,515	2,649	2,754
4. Total "scientific workers"	163	224	240	262	284	310	354	404	525	566	612	665	712	770	823	883	928
5. Social scientists	46	62	66	68	72	75	83	93	110	119	130	138	153	166	178	192	203
6. Natural scientists, military scientists, and engineers	117	162	174	194	212	235	271	311	415	447	482	527	559	604	645	691	725
7. With advanced degrees	37	62	66	71	75	79	82	86	90	97	104	113	129	144	159	175	192
8. Total "scientific workers" at research institutes	71	97	106	122	141	165	200	239	299	327	357	390	397	428	457	487	516
9. Social scientists	11	18	20	21	23	25	28	33	40	44	49	54	61	68	75	83	89
10. Natural scientists, military scientists, and engineers	60	79	86	101	118	140	172	206	259	283	308	336	336	360	382	404	427
11. Total "scientific workers" at universities	87	119	125	132	136	138	147	158	180	197	208	222	264	284	284	284	284
12. Social scientists	35	44	46	47	49	50	55	60	70	75	81	84	92	98	103	109	114
13. Natural scientists, military scientists, and engineers	52	75	79	85	87	88	92	98	110	122	127	138	172	186	181	175	170
14. Performing R&D	17	25	26	28	29	29	31	33	37	41	42	46	57	62	60	58	57
15. Total "scientific workers" at enterprises	27	33	35	36	38	39	41	43	46	42	49	52	52	58	82	113	128
16. Support workers assisting R&D in enterprises	54	66	70	72	76	78	82	86	92	84	98	104	104	116	164	226	256
17. Total R&D employment in industry	81	99	105	108	114	117	123	129	138	126	147	156	156	174	246	339	384
18. Full-time graduate students at R&D institutes	7	8	7	6	7	8	10	11	14	15	17	18	18	19	19	19	19
19. Graduate students performing R&D	4	4	4	3	4	4	5	6	7	8	8	9	9	10	10	10	10
20. Total R&D Employment	528	704	788	899	1,005	1,147	1,458	1,719	1,921	2,048	2,179	2,317	2,435	2,558	2,756	2,973	3,116
21. "Scientific workers"	108	141	151	168	189	212	249	288	349	374	406	443	454	490	534	585	622
22. "Scientific workers" with advanced degrees	25	41	44	48	53	58	62	67	67	73	79	86	94	105	116	126	139

[a] Sources and Methodology

Line 1:
1950-58—*N. kh. 1958*, p. 658-659.
1959 —*N. kh. 1959*, p. 589.
1960-66—*Trud v SSSR*, Moscow, 1968, p. 24-25.
1967-68—*N. kh. 1968*, p. 549.
1969-70—*N. kh. 1970*, p. 511.

Line 2:
1950-58—*N. kh. 1958*, p. 658-659.
1959 —Interpolated.
1960-67—*Trud v SSSR*, Moscow, 1968, p. 24-25.
1968-70—During 1963-67 the rate of increase was 1%. It is assumed that this rate was maintained during 1968-70.

Line 3:
1950-70—Line 1 minus line 2.

Line 4:
1950-58—*N. kh. 1958*, p. 843.
1959-62—*N. kh. 1962*, p. 582.
1963-64—*N. kh. 1964*, p. 699.
1965-67—*Trud v SSSR*, Moscow, 1968, p. 247.
1968 —*N. kh. 1969*, p. 694.
1969-70—*N. kh. 1970*, p. 656.

Line 5:
Social scientists include historians, philosophers, economists, philologists, geographers, jurists, pedagogists, artists, architects, and psychologists.
1950 —*Vysshcye obrazovaniye v SSSR*, Moscow, 1961, p. 204.
1955-57—Interpolated.
1958 —*N. kh. 1958*, p. 845.
1959 —*N. kh. 1959*, p. 756.
1960 —*N. kh. 1960*, p. 784.
1961 —*N. kh. 1961*, p. 703.
1962 —*N. kh. 1962*, p. 583.
1963 —*N. kh. 1963*, p. 590.
1964 —*N. kh. 1964*, p. 700.
1965 —*N. kh. 1965*, p. 710.
1966 —*Trud v SSSR*, Moscow, 1968, p. 248.
1967 —*N. kh. 1967*, p. 810.
1968 —*N. kh. 1968*, p. 696.
1969 —*N. kh. 1969*, p. 695.
1970 —*N. kh. 1970*, p. 657.

Line 6:
Natural scientists include physicists, mathematicians, chemists, biologists, geologists, agronomists, veterinarians, medical and pharmaceutical researchers, and research engineers.
1950-70—Line 4 minus line 5.

Line 7:
1950 —*Vestnik statistiki*, No. 4, 1962, p. 66 and *N. kh. 1960*, p. 784.
1955-70—Same sources as for line 5.

Line 8:
1950, 1958, 1960, 1964-65—*N. kh. 1965*, p. 709.
1955, 1959—*N. kh. 1960*, p. 782.
1956-57—*N. kh. 1959*, p. 754.
1961—*N. kh. 1962*, p. 582.
1962-63—*N. kh. 1963*, p. 589.
1966—Vornin, *op. cit.*, p. 214.
1967—A.A. Zyagin and V.N. Mosin, *Planirovaniye truda i zarabotnoy platy v NII i KB*, Moscow, 1969, p. 3, reports combined employment in Scientific Research Institutes (NIIy) and Instutions of Higher Education (VUZy). V.P. Yelyutin (ed) *Vysshaya shkola SSSR za 50 let*, Moscow, 1967, p. 144, reports 263,200 science workers at VUZy in 1967.
1968-69—Interpolated.
1970—Zyagin and Mosin, *op. cit.*, minus 263,000 assumed to be at universities.

Line 9:
1950, 1960—*Vysshcye obrazovaniye v SSSR*, Moscow, 1961, p. 204.
1955-59, 1961-70—The share of "scientific workers" in the social sciences employed in scientific research institutes increased from 23.9% in 1950 to 33.7% in 1960 (line 9 as a percentage of line 6). It is assumed that the increase occurred at 1 percentage point per year during the 1950s and continued at that rate in the 1960s. The shares are applied to the number of social scientists reported in line 5.

Line 10:
1950-70—Line 8 minus line 9.

Line 11:
1950-67—Same sources as for line 8.
1968-70—Assumed to remain at 1967 level.

Line 12:
1950-70—Line 5 minus line 9.

Line 13:
1950-70—Line 11 minus line 12.

Line 14:
1950-70—Reportedly, about one-third of the time of Soviet scientists employed by universities is spent performing research. N.A. Chinakal *et al* (eds), *Puti povysheniya effektivnosti nauchnogo truda*, Novosibirsk, 1966, p. 81. Line 14 is 33.3% of line 13.

Line 15:
1950-61—Beginning in 1962 the definition of "scientific worker" was adjusted to include technicians without a graduate degree carrying out scientific work at industrial enterprises and in project-design organizations. To the data reported for 1950-61, which is derived as a residual (see lines 8 and 11), was added an estimate for the reported category. It is assumed that the rate of growth for this category during 1962-65 (4.4% per year) prevailed during 1950-61.
1962-70—Derived as a residual; total scientific workers minus those employed in research institutes and universities.

Line 16:
1950-70—Assumed to be twice line 15.

Line 17:
1950-70—Sum of lines 15 and 16.

Line 18:
1950, 1960, 1965, 1969-70—*N. kh. 1970*, p. 661.
1955 —*N. kh. 1958*, p. 848, adjusted.
1956-59—*N. kh. 1959*, p. 760.
1961 —*N. kh. 1961*, p. 707.
1962-63—*N. kh. 1963*, p. 595.
1964 —*N. kh. 1965*, p. 715.
1966-68—*N. kh. 1968*, p. 700.

Line 19:
1950-70—Assumed to be one-half of line 18.

Line 20:
1950-70—Line 3 plus lines 14, 17, and 19 less line 9.

Line 21:
1950-70—The sum of lines 10, 14, 15, and 19.

Line 22:
1950-70—It is assumed that the proportion of all natural scientists, military scientists, and engineers with advanced degree (line 7) working in scientific research institutes is the same as the proportion of natural scientists, military scientists, and engineers—irrespective of degree held (line 10)—to the total number of natural scientists, military scientists, and engineers (line 6). It is assumed further that those natural scientists with advanced degrees not employed in scientific research institutes are employed at universities and spend one-third of their time engaged in R&D. Thus, line 22 is obtained by the following formula:

$$\text{Line } 22 = \frac{\text{line } 10}{\text{line } 6}(\text{line } 7) + 0.33\left[\text{line } 7 - \frac{\text{line } 10}{\text{line } 6}(\text{line } 7\right]$$

Table 13

United States: Employment in R&D [a]

Thousand Persons

	1950	1955	1958	1960	1965	1970
1. Federal Government	86.7	102.4	106.0	96.1	147.7	160.5
2. Scientists and engineers	37.7	44.5	46.1	41.8	64.2	69.8
3. Technicians	11.3	13.4	13.8	12.5	19.3	20.9
4. Support personnel	37.7	44.5	46.1	41.8	64.2	69.8
5. Industry [b]	239.8	427.8	640.2	671.0	846.6	919.6
6. Scientists and engineers	95.9	171.1	256.1	268.4	348.4	372.3
7. Technicians	48.0	85.6	128.0	134.2	149.8	175.0
8. Support personnel	95.9	171.1	256.1	268.4	348.4	372.3
9. Universities and colleges [b]	33.2	50.8	69.3	93.8	99.9	123.3
10. Scientists and engineers [c]	21.5	32.8	44.6	60.8	64.5	80.0
11. Technicians	0.9	1.6	2.4	2.6	3.2	3.3
12. Support personnel	10.8	16.4	22.3	30.4	32.2	40.0
13. Other nonprofit institutions [b]	6.5	10.7	14.3	17.9	34.9	40.5
14. Scientists and engineers	3.6	5.9	7.9	9.9	19.4	22.5
15. Technicians	1.1	1.8	2.4	3.0	5.8	6.8
16. Support personnel	1.8	3.0	4.0	5.0	9.7	11.2
17. Total employment in R&D	366.2	591.7	829.8	878.8	1,129.1	1,243.9
18. Scientists and engineers	158.7	254.3	354.7	380.9	496.5	544.6
19. Technicians	61.3	102.4	146.6	152.3	178.1	206.0
20. Support personnel	146.2	235.0	328.5	345.6	454.5	493.3

[a] Sources and Methodology

Line 1:

Sum of lines 2, 3, and 4.

Line 2:

1958, 1965, and 1970—National Science Foundation, NSF 72-300, *National Patterns of R&D Resources, 1953-72*, p. 34.

1960—Hugh Folk, *The Shortage of Scientists and Engineers*, Lexington, Mass., 1970, p. 69.

1950 and 1955—Derived as a residual, line 14 less lines 6 and 10.

Line 3:

Relationship derived from 1962 data in National Science Foundation, NSF 64-28, *Scientific and Technical Manpower Resources*, p. 65.

Line 4:

It is assumed that for each scientist or engineer performing R&D there is one clerical or other type of support worker.

Line 5:

Sum of lines 6, 7, and 8.

Line 6:

1958, 1960, 1965, and 1970—Same methodology as for line 2.

1950 and 1955—The number of scientists and engineers primarily employed in R&D was adjusted to a full-time equivalent basis using the relationship derived from 1954 data in National Science Foundation, NSF 68-30, *Employment of Scientists and Engineers in the United States, 1950-66*, p. 22, and NSF 72-300, *National Patterns of R&D Resources, 1953-72*, p. 34.

Line 7:

1950, 1955, 1958, and 1960—Based on the relationship derived for 1962 from National Science Foundation, NSF 64-28, *Scientific and Technical Manpower Resources*, p. 60.

1965—Based on the relationship derived for 1966 from Labor, Bureau of Labor Statistics, Bulletin 1609, *Scientific and Technical Personnel in Industry, 1961-66*, p. 58.

Line 8:

Same methodology as for line 4.

Footnote continued on following page.

Table 13

United States: Employment in R&D (Continued)

Line 9:
Sum of lines 10, 11, and 12.

Line 10:
1958, 1965, and 1970—Same as methodology as for line 2.
1960—Same methodology as for line 2 for scientists and engineers (including graduate students) employed in R&D at universities and colleges.
1950 and 1955—Same methodology as for line 6 for scientists and engineers (including graduate students) employed in R&D at universities and colleges.
1950, 1955, and 1960—Number of scientists and engineers employed at federally funded research and development centers (FFRDCs) computed using the average annual rate of growth for 1955 to 1958 derived from National Science Foundation data for 1950 and 1955 and the average annual rate of growth for 1959 to 1961 for 1960. The number of graduate students employed at FFRDCs in 1950 and 1955 is assumed to be the same as in 1954, and the number in 1960 is assumed to be the same as in 1961.

Line 11:
The number of technicians employed in universities and colleges is assumed to be negligible because of the use of graduate students as technicians. The number of technicians employed in FFRDCs is based on the relationship noted in line 3.

Line 12:
It is assumed that for every two scientists or engineers performing R&D there is one clerical or other type of support worker.

Line 13:
Sum of lines 14, 15, and 16.

Line 14:
1958, 1965, and 1970—Same methodology as for line 2.
1950 and 1955—Computed using the average annual rate of growth for 1955 to 1958 derived from National Science Foundation data.
1960—Computed using the average annual rate of growth for 1959 to 1961 derived from National Science Foundation data.

Line 15:
Same methodology as for line 3.

Line 16:
Same methodology as for line 12.

Line 17:
Sum of lines 18, 19, and 20.

Line 18:
1958, 1965, and 1970—Same methodology as for line 2.
1950 and 1955—Same methodology as for line 6.
1960—Sum of lines 2, 6, 10, and 14.

Line 19:
Sum of lines 3, 7, 11, and 15.

Line 20:
Sum of lines 4, 8, 12, and 16.

[b] Including professional R&D personnel employed at federally funded research and development centers administered by organizations in the sector.

[c] Including graduate students. The full-time equivalent of graduate students employed in R&D at universities and colleges and at federally funded research and development centers was 7,500 in 1958, 13,400 in 1965, and 18,700 in 1970.

Table 14

USSR: Annual Graduations in Engineering, by Field [a]

Engineering Field	1950		1960		1965		1970		
	Thousand Persons	Percent of Total Graduates	Thousand Persons	Percent of Total Graduates	Thousand Persons	Percent of Total Graduates	Thousand Persons	Percent of Total Graduates	1970 as a percent of 1950
Total graduations	*37.0*	*100.0*	*120.0*	*100.0*	*170.0*	*100.0*	*257.0*	*100.0*	*694.6*
Geology and survey of mineral resource deposits	1.7	4.6	3.9	3.2	3.2	1.9	5.1	2.0	300.0
Exploitation of mineral resource deposits	1.4	3.8	5.3	4.4	4.0	2.4	6.3	2.5	450.0
Power engineering	2.4	6.5	8.4	7.0	7.0	4.1	10.5	4.1	437.5
Metallurgy	1.4	3.8	3.9	3.2	4.8	2.8	6.5	2.5	464.3
Machine building and instrument making	9.1	24.6	30.6	25.5	46.0	27.1	69.0	26.8	758.2
Electrical engineering and electroinstrument making	1.4	3.8	8.1	6.7	24.6	14.5	40.5	15.8	2,892.9
Radio technology and communications	1.4	3.8	6.3	5.2	14.0	8.2	19.8	7.7	1,414.3
Chemical technology	2.6	7.0	5.7	4.7	10.1	5.9	16.1	6.3	619.2
Forestry engineering and technology of woods, cellulose, and paper	0.7	1.9	3.7	3.1	2.9	1.7	3.3	1.3	471.4
Technology of food products	2.3	6.2	3.5	2.9	4.8	2.8	7.9	3.1	343.5
Technology of consumer goods	1.2	3.2	3.1	2.6	3.2	1.9	5.4	2.1	450.0
Construction	4.9	13.2	17.7	14.7	21.3	12.5	30.3	11.8	618.4
Geodesy and cartography	0.3	0.8	0.6	0.5	0.9	0.5	1.0	0.4	333.3
Hydrology and meteorology	0.4	1.0	0.7	0.6	1.0	0.6	1.1	0.4	275.0
Transport (operations)	3.1	8.4	6.6	5.5	9.6	5.6	14.9	5.8	480.6
Agriculture	2.7	7.3	11.9	9.9	12.6	7.4	19.3	7.5	470.7

[a] Total graduations are from *N. kh. 1970*, p. 119. Other data are from *N. kh. 1970*, p. 646, and previous annual issues. Data for agriculture are derived as a residual. Because of rounding, components may not add to the totals shown.

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Table 15

United States: Distribution of Natural Scientists, by Field, and Number of Engineers [a]

	1950		1955		1958		1959		1960		1961		1962		1963		1964		1965		1966		1968		1969		1970	
	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent	Thousand Persons	Percent
Total natural scientists and engineers [b]	*550.8*	*100.0*	*806.3*	*100.0*	*995.1*	*100.0*	*1,051.3*	*100.0*	*1,097.3*	*100.0*	*1,245.5*	*100.0*	*1,394.3*	*100.0*	*1,273.5*	*100.0*	*1,320.1*	*100.0*	*1,301.3*	*100.0*	*1,412.8*	*100.0*	*1,543.2*	*100.0*	*1,577.3*	*100.0*	*1,710.0*	*100.0*
Natural scientists	146.3	26.6	208.5	25.9	268.9	27.0	287.5	27.3	300.5	27.4	316.0	25.4	334.8	27.8	355.1	27.9	378.8	28.7	395.5	29.1	416.8	29.5	*NA*	*NA*	494.8	31.4	610.0	35.7
Of which:																												
Physicists and mathematicians	27.2	4.9	40.2	5.0	53.7	5.4	59.0	5.6	62.7	5.7	66.1	5.3	71.7	6.0	77.3	6.1	83.5	6.3	87.9	6.5	92.8	6.6	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Chemists	51.2	9.3	72.8	9.0	89.3	9.0	94.3	9.0	98.4	9.0	101.0	8.2	105.6	8.8	108.7	8.5	113.5	8.6	116.0	8.5	119.3	8.4	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Biological scientists	19.9	3.6	27.3	3.4	39.0	3.9	42.5	4.0	44.7	4.1	46.9	3.8	48.9	4.1	51.3	4.0	54.3	4.1	55.6	4.1	56.8	4.0	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Geologists and geophysicists	11.2	2.0	15.3	1.9	18.4	1.8	19.1	1.8	18.5	1.7	18.7	1.5	19.2	1.6	20.4	1.6	21.5	1.6	23.6	1.7	24.4	1.7	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Other physical scientists [c]	9.7	1.8	16.5	2.0	19.7	2.0	20.5	1.9	21.2	1.9	22.8	1.8	23.3	1.9	24.4	1.9	25.5	1.9	26.2	1.9	28.3	2.0	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Agricultural scientists	17.2	3.1	22.6	2.8	27.7	2.8	29.9	2.8	30.9	2.8	32.8	2.6	35.8	3.0	39.0	3.1	42.1	3.2	44.7	3.3	47.6	3.4	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Medical scientists	9.2	1.7	12.9	1.6	19.6	2.0	21.1	2.0	22.7	2.1	25.5	2.0	28.8	2.4	32.7	2.6	37.2	2.8	40.9	3.0	40.2	3.3	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Engineers [d]	404.6	73.5	597.8	74.1	726.1	73.0	763.8	72.7	796.7	72.6	929.5	74.6	869.4	72.2	918.3	72.1	941.3	71.3	965.8	70.9	996.0	70.5	*NA*	*NA*	1,082.5	68.6	1,100.0	64.3

[a] Sources

1950-66—National Science Foundation, NSF 68-30, *op. cit.*, p. 20, *passim*.

1968-70—Estimated at the National Science Foundation.

[b] Because of rounding, components may not add to the totals shown.

[c] Including metallurgists and other specialties classified by the USSR as engineering.

[d] Including all persons working in engineering positions, irrespective of degrees held.

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APPENDIX B

Occupational Content of the "Scientific Workers" Category as Defined in the Soviet 1970 Census[a]

Directors and all faculty members of Institutions of Higher Education (VUZy), except teachers of physical culture
Directors of scientific-research establishments
Agroclimatologist-agronomist
Agroclimatologist, other
Agrometeorologist-agronomist
Agrometeorologist, other
Agronomist scientific worker
Agrochemist scientific worker
Academician (*Akademik*)
Academician—department secretary
Anthropologist-physician
Anthropologist, other
Archeographer scientific worker
Archeographer, other
Archeologist scientific worker
Archeologist, other
Archivist scientific worker
Architect scientific worker
Graduate student (*aspirant*)
Assistent[b] agronomist
Assistent architect
Assistent physician
Assistent of clinic
Assistent of laboratory science
Assistent artist
Assistent other than above, in scientific research establishments
Astronomer scientific worker
Aerologist engineer
Aerologist, other
Bacteriologist physician scientific worker
Bacteriologist scientific worker
Bacteriologist (in scientific research institutions)
Bibliographer scientific worker
Bioclimatologist scientific worker
Biologist-agronomist
Biologist-physician
Biologist-laboratory worker
Biologist scientific worker
Biologist, other
Biophysicist
Biochemist-physician
Biochemist laboratory worker
Biochemist scientific worker
Biochemist, other
Botanist laboratory worker
Botanist scientific worker
Botanist, other
Virologist-bacteriologist
Virologist-physician
Virologist, other
Vice President, Academy of Science
Orientalist
Physician scientific worker
Geneticist
Geobotanist
Geographer scientific worker
Geologist scientific worker
Geometrician
Geomorphologist
Geophysicist scientific worker
Geochemist scientific worker
Hydraulics scientific worker
Hydrobiologist
Hydrogeologist scientific worker
Hydrographer scientific worker
Hydrodynamics scientific worker
Hydrologist scientific worker
Hydroreclamation scientific worker
Hydrometeorologist
Hydromechanics scientific worker
Histologist
Active member of the Academy of Sciences
Doktor Nauk (persons with title Doctor of Science), except in VUZy
Candidates for the degree *Doktor Nauk*
Reclamation scientific worker
Metallurgist scientific worker
Meteorological engineer
Meteorological laboratory worker
Meteorologist scientific worker
Meteorologist, other
Mycologist scientific worker
Holders of title "Honored Scientist"
Zoogeographer
Zoologist laboratory worker
Zoologist, other
Engineer scientific worker
Art critic

[a] The categories listed in this Appendix are those given in *Sistematicheskiy slovar' zanyatiy*, Moscow, 1969, p. 59-62, and are given in the same order as they appeared in that publication.

[b] *Assistent* is a scholarly title analogous to the title "Assistant Professor" in the United States.

Researcher scientific worker
Researcher, other (at scientific research establishments)
Historian archivist
Art historian
Research historian
Literature historian
Historian scientific worker
Historian, other
Ichthyologist
Kandidat Nauk (persons with Candidate of Science), except at VUZy
Cinematographer
Climatologist
Consultant on scientific disciplines (except at VUZy)
Linguist
Literature specialist
Lithologist
Magnetization engineer
Magnetization, other
Mathematician scientific worker
Paleontologist-geologist
Paleontologist, other
Pathophysiologist
Petrographer scientific worker
Microbacteriologist
Microbacteriologist physician (at scientific research institutes)
Microbacteriologist laboratory worker
Microbacteriologist (at scientific research institutes)
Mineralogist
Museum operator
Musicologist
Scientific worker laboratorian
Scientific worker, other
Scientific worker reviewer (academies, scientific research establishments)
Scientific worker-director
Scientific worker-associate
Oceanographer
Orientalist scientific worker
Ornithologist
Seismologist
Synoptical scientific worker
Sociologist
Theatrical specialist
Technologist scientific worker
Toxicologist scientific worker
Scientific secretary
Scientific curator of museum
Scientific expert
Pharmacologist physician
Pharmacologist, other
Physicist scientific worker
Physiologist physician
Plankton specialist
Soil scientist scientific worker
Professor—consultant
Professor (except at VUZy)
Chairman, Department of the Academy of Sciences
Chairman, of the Presidium of a branch of the Academy of Sciences
President of the Academy of Sciences
Psychologist
Psychophysiologist
Radiophysicist engineer
Radiophysicist, other
Roentgenologist scientific worker
Roentgeno-radiologist scientific worker
Director, agrobiological station (scientific)
Director, Academy (scientific research)
Director, of independent archives (in republics, krays, oblasts, districts)
Director of archival preservation
Director of *aspirants* (except in VUZy)
Director of biological science stations
Director of botanical gardens
Director of bureaus of science
Director of computer centers (science)
Director of hydrometeorological station (except stations associated with transportation)
Physiologist laboratory worker
Physiologist scientific worker
Physiologist, all other
Philologist
Director of group, laboratory, or office (at scientific research and design establishments except those serving construction)
Director of National Forest
Director of zonal scientific research stations
Director of zoos
Director of scientific research institutes
Director of institutes for scientific information
Director of design institute (except those serving construction)
Director of the Cabinet (at scientific research institutes and design organizations except those serving construction)
Director of design bureau (except those serving construction)
Director of scientific research laboratory (at enterprises and establishments)
Director of problem laboratory
Director of laboratory (at scientific research institutes and design bureaus except those serving construction)
Director of meteorological station
Director of scientific administration for the preservation of nature
Director scientific research
Administration
Director of observatory
Director of experimental station (independent)
Director of experimental economic research administration
Director of a department (holding a scientific, technical, or production specialty) at scientific research or design establishments, except those serving construction and VUZy

Director of a department (without a specialty) at scientific research or design establishments, except those serving construction
Director of independent design bureau except those serving construction
Director of radiometer station
Director of radiometeorological station
Director of academic branch at scientific research institute
Director of branch institute at scientific research institute
Director of land slippage station
Philosopher
Phytopathologist scientific worker
Chemist biologist
Chemist scientific worker
Curator of funds scientific worker
Corresponding member of the Academy of Sciences
Economic geographer
Economist scientific worker
Electrophysicist scientific worker
Embryologist
Endocrinologist husbandry specialist
Power engineering scientific worker
Entomologist scientific worker
Ethnographer
Linguist

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APPENDIX C

Occupations and Duties Associated With Soviet R&D*

Occupational Classification	Duties
Senior research worker:	
Doctor of Science	Independently formulates large basic and applied research ideas, goals, principles, and methods of solution; directs branch development; actively guides the preparation of cadres; is involved in creative literature activities; leads scientific-technical participation in deciding most work goals in research and design; carries out especially complex calculations; consults with other institutions on scientific-technical questions.
Candidate of Science	Does the above but in a narrower scientific area; writes complex accounts and works competitively on complex technical goals.
Junior scientific worker:	
Candidate of Science	Participates in carrying out basic and applied research or design work under the direction of a senior scientific worker or laboratory head; independently solves narrow (single) theoretical questions; works out the methods to be used in experiments; writes up sections of accounts and of technical documentations.
Engineer	Conducts research and design work under the direction of a junior scientific worker or senior engineer; independently carries out calculations of measuring methods; writes up sections of accounts and of technical documentations.
Head designer, chief specialist	Independently works on design goals or large sections, directs research, writes up the most complex sections of technical documentations; enters into agreement on scientific questions with other institutions; works out technical goals for subdivision.
Head engineer and engineer-designer—Category I	Independently or as the head of a group of workers engages in a narrow part of applied research or design in connection with a stated goal; designs and calculates more complicated elements of measuring methods; chooses scientific-technical solutions within the limits of stated goals; parcels out the work for the group; compiles accounts for the completion of work and for technical documentation.
Senior engineer and engineer-designer—Category II	Independently or as the head of a group of from three to six persons, conducts applied research or design within the limits of technical knowledge; writes sections of accounts; turns out simple technical documentation and presents it for the examination of head engineers or designers (category I); designs more complex documentation.

* Ye.I. Kissel', *Organizatsiya truda v issledovatel'skikh i proyektnykh uchrezhdeniyakh*, Moscow, 1969, p. 173-174.

Engineer and engineer-designer—Category III	Works out simple diagrams, designs, and processes under the direction of a more qualified specialist; carries out simple calculations for the majority of experiments, tests, and measures.
Senior technician	Under the direction of an engineer, executes simple diagrams and designs; regulates measuring and test equipment; participates in the preparation of prototypes; has excellent knowledge of measuring techniques and methods of measuring; registers the results of experiments.
Technician	Participates in the preparation of prototypes and testing and tuning simple equipment; has a knowledge of measuring devices, regulates their use, and registers the results of measures.
Laboratory assistant (without specialized education)	Helps more highly trained science workers, providing them with needed accessories (materials, components, technical documents, literature, measuring instruments, etc.); moves equipment and instruments, etc.